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Development of the Gippsland Lakes Entrance Since 1851

By J. J. Fryer*

Abstract: A permanent entrance to the Gippsland Lakes was constructed during the latter half of the 19th Century, to facilitate ship access into Gippsland. A sand bar developed around this entrance on the seaward side, restricting the operation of vessels and development of the port at Lakes Entrance. The artificial entrance has also modified conditions within the lakes and caused erosion and accretion along the Ninety Mile Beach.

This paper presents a study of the major factors influencing the dynamic physical system of the Entrance region as obtained from geological and historical data, together with field and laboratory observations. Estimates are made of the magnitude and direction of littoral drift along this section of the Ninety Mile Beach.

INTRODUCTION

Since Lt. Bass first sailed into the Strait which now bears his name, this stretch of sea has been of great value in the development of Australia, providing among many other valuable resources an important transportation corridor.

Before the railways had reached into eastern Victoria, early settlers were able to ship their goods to Melbourne through the extensive river and lake systems of Gippsland and out into Bass Strait. These lakes have an area of some 40,000 ha behind the high coastal sand dunes of the Ninety Mile Beach. The lakes formerly discharged into Bass Strait at their eastern end, near Red Bluff, a 20 m high cliff located approximately 8 km E. of the present town of Lakes Entrance.

Under the influence of waves, tides and currents, the natural entrance is known to have migrated back and forth over a distance of several kilometres during the latter half of the 19th Century. The entrance also varied in both width and depth, making it difficult for sailing ships and steamers to cross the offshore sand bar and enter the lakes from Bass Strait.

After an earlier unsuccessful attempt, a permanent entrance to the lakes was created on the 14th June, 1889, but after a few years an offshore sand bar also encircled this entrance and restricted access.

With the coming of the railways to East Gippsland, the original shipping traffic declined, but the progressive development of Lakes Entrance into one of the major fishing ports in Australia has maintained the need for a permanently deep entrance to the lakes. More recently, the discoveries of oil and natural gas offshore have attracted further interest in the port, since there are few natural harbours along this portion of the Victorian coast.

In 1963 the Public Works Department of Victoria commenced an investigation of the major factors influencing the formation of the sand bar at the entrance. This investigation included the use of hydraulic model techniques to simulate the development of the entrance bar.

DEVELOPMENT OF THE ENTRANCE

Natural Entrance

Geologically, the Gippsland Lakes were formed during the late Pleistocene and Recent periods by the creation of successive frontal sand dunes under wind and wave action, together with comparatively minor fluctuations in sea level (Bird (1965) and Jenkin (1968)). Because the natural entrance has been located at the eastern extremity of the lakes, it has been suggested that the dominant littoral drift of beach sand in the area has been from west to east (Coode 1879) and Bird (1965, p. 95)). The magnitude and variability of littoral drift can be extremely important in the design of coastal engineering works.

The large oscillatory migration of the natural entrance in historical times suggests that the

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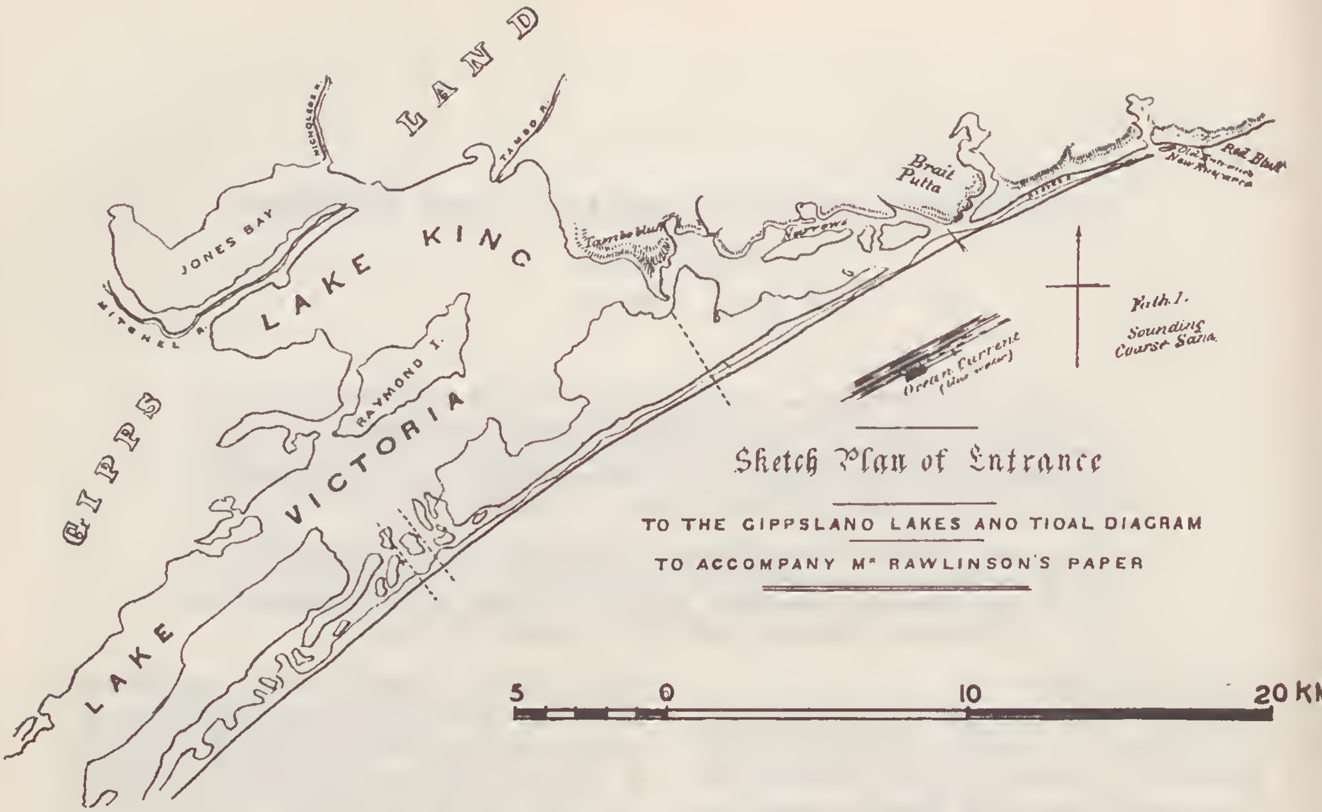

FIG. 1—Gippsland Lakes Entrance in 1863 by Rawlinson. (Courtesy of Royal Society of Victoria).

littoral drift is more nearly in dynamic balance from both directions, and large in magnitude.

Early accounts of the discovery of the Gippsland Lakes entrance were discussed by Wakefield (1969).

In 1851, G. Syme, in his Coast Survey 3A, located the then 300 m wide entrance 2·6 km west of Red Bluff. However, in a report to the Royal Society of Victoria, the Honorary Secretary, T. E. Rawlinson (1865) indicated that in 1855 the entrance was about 1·5 km west of Red Bluff but that it had gradually moved closer to the Bluff by 1862/63 when he re-inspected it. Following the drought of 1862-63 when the entrance could be crossed on foot, a flood in (mid) 1863 re-opened the old entrance and a new entrance 1/2 km to the west, but the former entrance gradually closed (Fig. 1).

Later plans show the entrance further west. A report and plan (Pl. 8) by Sir John Coode in 1879 described the migration of the entrance in the following terms:

'The position of the entrance has varied greatly from time to time. It appears, from a report by the late Captain Ferguson, that in the year 1861 the entrance was within 200 yards of Red Bluff—the point marked X in red on Drawing No. 1— and that after remaining open there for about eight months, it began to move to the westward towards Lake Bunga, where it remained open until February, 1863, when it became nearly closed for three days, after which it broke out again and had remained open until the date of his report—2nd November, 1864.
According to information collected at the time of my examination, the most westerly position at which the entrance has ever been known is that marked by the letter Y in red on Drawing No. 1, which is about a mile further to the westward than at the time when the special survey was made in 1879.

A plan by Ferguson in October, 1864, shows both an old entrance 200 m W. of Lake Bunga and a new entrance 300 m further W. with a best navigable depth of 1·5 m below low water.

A correspondent to the Bairnsdale and Bruthen News on 1st July, 1889, refers to five new entrances having formed during the previous 13 years and states that the former entrances quickly closed. However, Coode refers to two navigable entrances remaining open for four months on one occasion.

TABLE 1

LOCATION OF ENTRANCE TO GIPPSLAND LAKES
1851-1879

Date	*Distance W. of Red Bluff in m*	*Surveyor*	*Comments*
1851	2,600	G. Syme	Lands Dept. Coast Survey 3A.
1855	Approx. 1,500	T. E. Rawlinson	*Trans. & Proc. R. Soc. Vic.* 6:84-90, 92-8. Entrance moving further eastward.
1861	180	Capt. Ferguson	Quote by Coode. Entrance stationary for 8 mths.. then moved west to L. Bunga.
Feb. 1863	Approx. 1,400	Capt. Ferguson	Coode quoting Ferguson, entrance stationary.
Sept. 1863	Approx. 1,400	T. E. Rawlinson	*Trans. & Proc. R. Soc. Vic.* 6:92-8, old entrance 1/2 km further east.
Oct. 1864	1,740	Capt. Ferguson	Chart held by PWD: shows an old entrance 1,480 m from Red Bluff, together with offshore soundings.
Nov. 1866	2,560		Chart held by PWD shows an old entrance 1,620 m from Red Bluff.
Feb. 1867	2,640	Okaugtue (?)	Detailed survey of natural entrance and site of present entrance, including offshore soundings, held by PWD in two sheets.
Sept. 1869	1,840	Lt. H. J. Stanley, R.N.	Plan of the entrance to the Gippsland Lakes showing place of proposed entrance and the prevailing winds and tides in the locality, held by PWD. Notations on sand bar around entrance refer to changeable depth and closure of entrance by strong winds with sluggish stream. Flood tide from east, prevailing breezes and gales from SW., occasional SE. gales.
1871	Approx. 2,100	Lt. Stanley	Survey from Merriman Ck. to C. Howe, basis of Admiralty Charts.
1879	3,300	Sir J. Coode	Plan showing existing and proposed entrance to lakes with widest known range in location of entrance 180 m (1861) to 5,000 m from Red Bluff.
N.A.	Max. 5,000		Coode's report.

The known locations of the entrance between 1851 and 1879 are given in Table 1.

PERMANENT ENTRANCE

In 1869, plans were prepared for the creation of a permanent entrance, 120 m wide, opposite Jemmys Point, 8 km W. of Red Bluff. Excavations through the sand dunes commenced in 1870 but were abandoned in 1874 after a heavy gale caused the excavation to be filled with sand.

After Sir John Coode's recommendation of 1879, work was resumed in 1883 on the same site and the final break-through occurred during a storm on 14th June, 1889. A Royal Commission Report (1927) incorrectly referred to the opening having occurred in 1888.

The Bairnsdale and Bruthen News on Monday, 17th June, 1889, reported on the opening and expressed the feeling of the settlers as follows:

THE NEW LAKES ENTRANCE WORKS

Success at Last

An Opening Made by the Ocean

The intelligence received on Saturday morning that the barrier (12,000 sand bags) at the new entrance works had been broken away and a deep channel formed, will be received with gratification throughout the entire province, and indeed the whole colony. There will be some surprise felt that despite the heavy rains and the consequent increased volume of water in the Lakes, the entrance was formed from the Ocean. There has been some very heavy seas prevailing along the Ninety Mile Beach for the past few days accomplished by strong westerly winds. It was to this circumstance that the breach in the barrier was due.

The sudden inrush of water from Bass Strait, which carried dredges and sand bags before it, temporarily flooded part of the township of Cunningham (Lakes Entrance). Later, the permanent entrance assisted in minimising the previous periodic flooding of the township when the natural entrance was closed.

Initially there was considerable scour within the permanent entrance channel, but a bar soon began to form in the ocean outside the entrance. The bar continued to develop, encircling the entrance and gradually moving offshore until by about 1925 it had attained a quasi-equilibrium condition. The 100 m broad bar then had a best navigable depth of around 3 m at a distance of 400 m from the head of the channel training piers.

The original training walls were constructed in timber, but the effect of teredo worms decreased their strength and the outer ends of the piers were subsequently destroyed by storms between 1897 and 1899. Stone and concrete were used to strengthen the piers between 1903 and 1913, but the original outer ends were abandoned.

Over the years, the best navigable depth across the ocean bar has frequently moved rapidly from side to side in its location and generally varied in its depth of from about 2 to 3 m below low water.

Sand has also accumulated alongside the outer faces of the two pier heads, particularly on the eastern side where the beach face has now advanced approximately 180 m and only regains its original alignment several kilometres further to the east, Pl. 9A. On the west, the beach has advanced about 100 m near the pier head, but it has eroded 150 m at a point 2 km further west and regains its original alignment some 5 km from the entrance, Fig. 2.

Assuming that the original beach alignment did not change between the survey of 1851 and when the pier heads commenced to cross the beach in 1888, the rate of erosion can be estimated from aerial photographs in 1940, 1963 and 1966. During the first 50 years, the average rate was 2·2 m per year, reducing to 1·7 m per year between 1940 and 1963. Wind fences, built on the upper beach in about 1965, appear to have arrested this erosion.

The volume of sand eroded on the western side of the entrance is estimated to be of the order of 8 million cubic metres. The volume trapped within the new entrance sand bar is about 11 million cubic metres and a further 2 million cu m has accumulated on its eastern side.

These volumes allow an estimate to be made of the total average annual littoral drift of sand from both directions along this part of the Ninety Mile Beach. If it is assumed that all the drift was trapped initially and that equilibrium was achieved over say 75 years at a uniformly decreasing rate, the average total littoral drift would be of the order of 300,000 cu m per year.

From surveys, a comparable estimate of 300,000 cu m per year for littoral drift can be made from the 1·4 million cu m of sand trapped on the bar in the 36 months immediately following the opening of the entrance, after allowing 0·4 million cu m of sand scoured out of the channel.

Sand on the Lakes Entrance bar has a median diameter of about 0·4 mm and contains only a few percent of shell. Similar sand occurs in the high

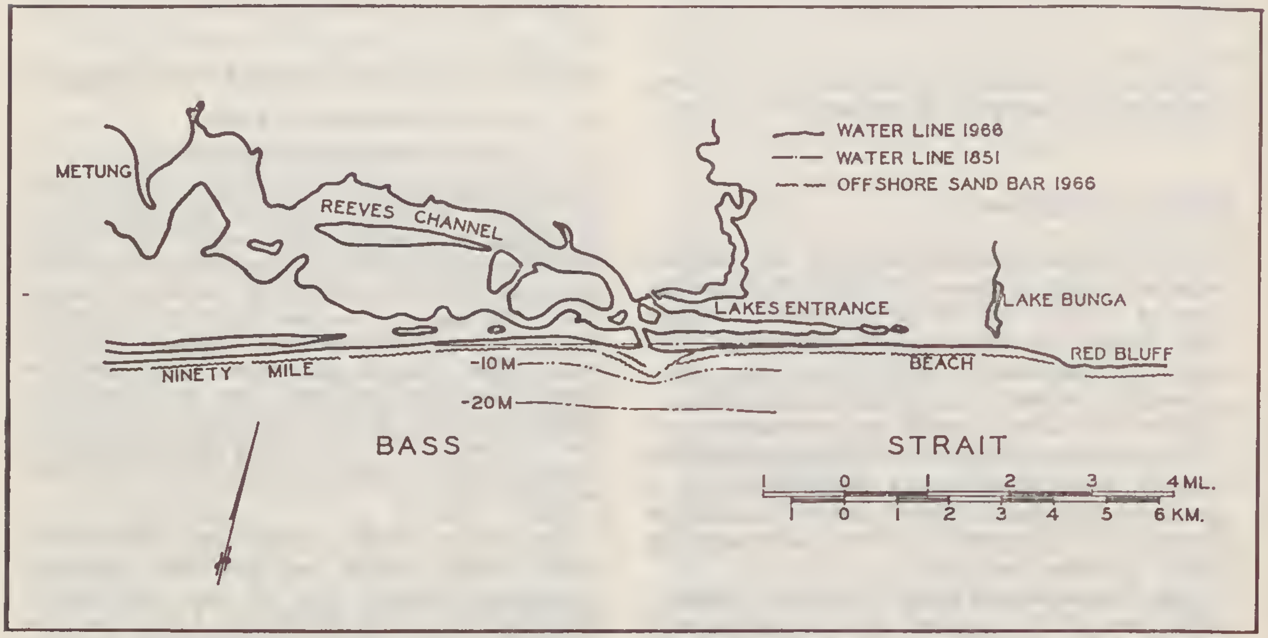

Fig. 2—Ninety Mile Beach in 1966.

wave energy zones on the beach and in the breaker zones for 10 km on either side of the entrance. Very fine sand with a median diameter of about 0·15 mm occurs in two zones situated on either side of the entrance at a depth of about 10 m. This fine sand may have come from deposits of similar sized sand which exists inside the lakes. The offshore deposits vary over several kilometres in their extent and distance from the entrance but there is insufficient data to indicate drift patterns. However, the drift of this fine sand does not necessarily correspond to the drift of the coarser sand in the surf zone.

FORCES AFFECTING THE ENTRANCE

The major forces acting on the entrance are due to waves, tides and river flows.

The average annual river discharge through the entrance is about 3·3 x 10^9 cu m, corresponding to approximately 100 cu m per second. Average monthly flows range from about 33 m^3/s in February to about 190 m^3/s in September. In severe droughts, evaporation in the lakes exceeds the river flow, causing a net inflow of water from Bass Strait, while during the major flood in December, 1934, the outflow was probably about 5,000 m^3/s.

Although the tidal range in Bass Strait near Lakes Entrance is relatively small, the large area of the Gippsland Lakes subject to tidal effects causes a strong tidal flow through the entrance. The semi-diurnal tides recorded in the Cunningham Arm of the lakes, just inside the entrance, have a spring and neap range of about 0·5 m and 0·3 m respectively. In the main body of Lake King and Lake Victoria, these tides attenuate to 15% of the amplitude inside the entrance and have a phase lag of 3 hours. Offshore, the tides are estimated to have about twice the entrance amplitude. Rawlinson recorded ocean tides for several weeks in 1863 and it appears that he obtained a similar result. Ferguson's chart of October, 1864, gave a spring tidal rise above datum of 1·2 m while Coode referred to a spring tide range of 1 m.

In February, 1963, the maximum tidal velocity measured in the main entrance channel was 2·5 m/s on a spring tide, corresponding to a peak discharge of 1,000 m^3/s. However, the average tidal flow over a tidal cycle is about 500 m^3/s for a mean tidal range, or five times the average river flow.

The flood tide comes in approximately radially over the ocean sand bar but the ebb tide runs out as a jet from the pier heads. The ebbing current is at its maximum at low tide and these two effects accentuate the breaking of waves on the bar, bringing sand into suspension and scouring a shallow channel through the bar. On the flood tide, some of the sand on the bar brought into suspension by wave action is carried through the entrance and deposited inside the lakes until it is returned to the bar by subsequent ebb tides.

Wave action also carries sand around the bar to maintain general continuity in the littoral drift along the coast.

Storm waves from WSW. with a maximum height of about 6 to 9 m and period of 6 to 8 seconds have been recorded offshore in the vicinity of the oil rigs, but seas with a maximum height of about 2 m are common.

Waves are refracted as they approach the shore and the daily incident wave direction on the Lakes Entrance bar has been recorded. While it is difficult to estimate wave characteristics visually, records during 1965/66 indicate that easterly waves were almost twice as frequent as south-westerly waves, while very few waves came from the S.

Wave observations are made twice daily at the lighthouse at Gabo Island and Wilsons Promontory. These waves are classified into either local wind generated seas of different heights or ocean swells from distant storms with different states of height and length.

Over the period 1960 to 1964 inclusive, half of the swell waves at Wilsons Promontory came from the SW. and a quarter from the E. From both directions, these swell waves were mostly low (0-2 m) in height with short or average length (0-200 m). Seas were more variable but were mainly from the W. and NE. in similar proportions. Gabo Island is more sheltered from the SW. and southerly swells dominate with 36% of the occurrences, followed by 19% from the E. and 15% from the SE. Easterly swells are more frequent in summer. However, seas from the SW. sector contributed almost half of the total occurrences followed by the NE. sector with over a quarter.

Lakes Entrance is approximately mid-way between these two lighthouses, and the offshore wave conditions will be approximately the average of the two sets of observations. Estimates of the littoral drift produced by the various groups of seas and swells can be made by assigning typical characteristics for each group and calculating the wave energy and refraction.

Swell waves at Lakes Entrance convey approximately six times more energy to the coast during the year than the local seas. In a storm, seas can be very large but they are short in duration compared with the persistent swells.

The swell wave energy from the SW. is concentrated around waves with height of 3 m and period of 9 seconds. From the E., the corresponding waves have a period of about 8 seconds but are slightly higher and contain similar energies per wave. Although the south-westerly waves occur more frequently, their effectiveness in transporting sand is reduced by their angle of attack on the shore. In an earlier assessment of wave conditions, the effect of the south-westerly swells reaching Lakes Entrance from the western end of Bass Strait was under-estimated (Jenkin (1968, p. 89)).

The average littoral drift produced by all swell waves is estimated to be approximately 600,000 cu m per year, half coming from the E. and half from the W. The effect of seas would slightly increase this estimate of the littoral drift.

HYDRAULIC MODEL

A pilot hydraulic model was constructed to simulate the major effects of waves, tides and river discharge on the movement of sand in the vicinity of the entrance. The model extended over a semi-circular area of the ocean within 1·4 km of the entrance at a horizontal scale of 1:300 and vertical scale of 1:100.

Waves of different height and period were generated by a 9 m long oscillating vertical blade. Wave directions were varied by rotating the model which was mounted on a turntable. Tidal heights and currents through the entrance were simulated by a recirculating pumping system which automatically changed the tidal current direction every 12·5 minutes, representing 6·2 hours in the prototype. River flow was introduced upstream of the entrance.

A fine beach sand was employed to simulate the coarser sand at Lakes Entrance as no light-weight material was available at that time. Sand traps were located at both ends of the beach and inside the entrance. As required, sand was fed into the model at these locations.

The model commenced operation before the analysis of prototype wave data was available and the optimum test conditions to simulate known bottom configurations were obtained by trial. Frontal waves of 3 m height by 9 s period achieved a good simulation of the beach, longshore bar and bottom profile known to have existed before the permanent entrance was constructed.

After a further series of trials with the permanent entrance in position, the model was able to simulate the development of the bar and beach at the entrance from the time it was opened to its present equilibrium condition as shown in Pl. 9B.

Because of the comparatively heavy bed material in the model, it was found necessary to increase the scaled tidal and river flows to locate the entrance bar in its correct prototype position further offshore. Acceptable entrance bar configurations and ocean beach accretion and erosion patterns on either side of the entrance were obtained with 3 m x 9 s waves applied alternatively after each tidal cycle from 10° either side of the frontal wave position.

Although equal wave energy was applied symmetrically from both directions, an asymmetrical beach alignment was created because of the oblique angle of the ebb current through the entrance.

A greater proportion of waves from either the E. or W. produced a poorer simulation of the beach alignment and bar formation. Large storm waves rapidly eroded the beach and destroyed its relatvely smooth alignment as well as creating a pronounced breaker line trough in the entrance bar. With no waves, sand carried out from the lakes formed a long tongue-shaped deposit offshore to just below the low water line.

DISCUSSION

The determination of the dominant direction of littoral drift can be assessed from a number of factors, some of which appear to be in conflict in the vicinity of Lakes Entrance.

The location of the entrance to the Gippsland Lakes at its eastern extremity has been interpreted by Coode (1879) and Bird (1965, p. 45) to be due to a predominance of south-westerly wave action.

The general migration of the natural entrance over several kilometres towards the E. between 1851 and 1861 followed by a general movement towards the W., suggests that the littoral drift from both directions is more nearly in dynamic balance and large in magnitude. The present entrance also exhibits lateral fluctuations in the location of the best available depth for navigation.

The natural entrance was also located in the curved transition between two generally long straight coast alignments extending from near Port Albert in the W. to Point Hicks in the E.

Usually, the creation of a barrier across a beach causes an accumulation of sand on the updrift side and erosion on the downdrift side. This erosion and accretion continues until a new stable alignment is established when the continuity of drift is restored. At Lakes Entrance, the large accretion on the eastern side of the permanent entrance, together with the large erosion of the W. suggests that the dominant drift has been from the E. over the past 80 years. This is also supported by the alignment of the beach just E. of Red Bluff being further advanced offshore than the beach just W. of the Bluff. Several small lakes and rivers further to the E. of Red Bluff also tend to have their mouths located at the western end of ocean sand-pits.

Although in the model the tidal current effects were exaggerated, the results indicated that the accretion and erosion along the ocean beach near the entrance need not be due to a dominant littoral drift from the E. but arise from the oblique orientation of the entrance channel, coupled with a balanced littoral drift from both directions.

Estimates of littoral drift based on wave analysis further support the concept of a balance between the drift from both directions at Lakes Entrance.

Three estimates of the magnitude of the total littoral drift based on the initial rate of deposition of sand at the permanent entrance, the longer term changes in volume and the wave energy analysis all indicate a large drift of the order of 300,000 cu m per year.

CONCLUSIONS

The entrance into the Gippsland Lakes from Bass Strait has continued to be a significant factor in the development of this region of Victoria.

The location, size and number of natural entrances changed frequently prior to the construction of the permanent entrance in 1889.

Since 1889, the Ninety Mile Beach has been eroded on the western side of the permanent entrance and sand has deposited around the entrance, particularly on the eastern side, and offshore where a bar has developed.

At present, the entrance region has achieved a new equilibrium situation and the estimated total annual littoral drift of about 300,000 cu m is considered to have been derived approximately equally from the E. and W. Wave action is the dominant force controlling the depth of water on the bar while the distance offshore is mainly dependent on the current through the entrance.

Further from the entrance on both the eastern and western sides, the net littoral drift is likely to be towards the entrance.

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DESCRIPTION OF PLATES

PLATE 8

Gippsland Lakes Entrance in December, 1879 by Coode. This is a 7:1 reduction of the original pen-line drawing with water-colour tints on linen-backed paper, held by the Public Works Department. (Courtesy of Public Works Department of Victoria).

PLATE 9A

Entrance, February 20, 1963. (Courtesy of Department of Crown Lands and Survey).

PLATE 9B

Model Simulation of Present Entrance Conditions. (Courtesy of Public Works Department of Victoria).